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L. Forde Kohler, R.J. Dinus, E.W. Malcolm, A.W. Rudie, R.L. Farrell, and T.S. Brush

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IMPROVING SOFTWOOD MECHANICAL PULP PROPERTIES WITH *OPHIOSTOMA PILIFERUM*

L. Forde Kohler
Graduate Student
IPST
Atlanta, GA 30318
USA

R.J. Dinus
Professor
IPST
Atlanta, GA 30318
USA

E.W. Malcolm
Professor
IPST
Atlanta, GA 30318
USA

A.W. Rudie
Associate Professor
IPST
Atlanta, GA 30318
USA

R.L. Farrell
Chief Operating Officer
Executive Vice President
Sandoz Chemicals Biotech
Research Corp.
Lexington, MA 02173
USA

T.S. Brush
Project Leader
Sandoz Chemicals
Biotech Research
Corp.
Lexington, MA 02173
USA

ABSTRACT

Earlier reports showed that chip treatment with a nonstaining fungus, *Ophiostoma piliferum,* reduced pulp extractive contents. Producers using the fungus have seen increases in paper strength properties. In laboratory scale trials, reductions in extractive content of loblolly pine (*Pinus taeda*) wood meal by one-, three-, and five-week treatments were similar to those reported earlier. Chips from the same wood were refined with a Sprout-Waldron atmospheric refiner to various CSF levels. Resultant pulps were used to make handsheets. Pulp and handsheet properties were evaluated using TAPPI Standard Methods. Tensile strength increased marginally, while tear strength increased significantly. Treated chips yielded pulps with increased fiber lengths and decreased fines contents.

During a pilot scale trial to examine fungal treatment effects, southern pine chips were treated with *O. piliferum*, and aged for five weeks. Control chips were frozen during this time period. Chips were refined in a pressurized double-disc refiner, while an atmospheric double-disc refiner was used for secondary refining. TAPPI Standard handsheets exhibited increased tensile and tear strengths. Refining energy consumption decreased with fungal treatment. Increased fiber lengths and decreased fines contents were not evident in the pilot scale pulps. Increased strength properties may result from greater intrinsic fiber strength and increased bonding.

INTRODUCTION

The fungus, *Ophiostoma piliferum* (*O.piliferum*), is used to control pitch problems in paper production. Natural pitch is defined as low-molecular-weight oleophilic materials extracted from wood chips by neutral, nonpolar, organic solvents. Pitch contains triglycerides, fatty acids, diterpenoid resin acids, sterols, waxes, and other compounds, some of which are not well characterized (1).

Cartapip 97®(Cp) is a commercially available albino strain of *O.piliferum* (Sandoz Chemicals Corp.), which does not stain wood, as do most blue stain fungi (2). In addition to controlling pitch problems and preventing blue stain, Cp chip treatment yields products with improved strength and runnability characteristics (3). The objectives of this work were to document any strength changes in mechanical pulps produced from loblolly pine (*Pinus taeda*) chips treated with Cp and explore probable causes.

MATERIALS AND METHODS

Wood Source

Lab scale.
Three half-sib, loblolly pine trees were obtained in southeastern Georgia to use as the wood source for this project. Trees were cut into boards; the boards were sawn into blocks and then uniformly cut into chips by hand with a band saw. To increase uniformity, care was taken to remove knots and associated compression wood. Chips were stored frozen until used. All experiments were conducted with random mixtures of nonsterile chips from all trees, including early wood, late wood, juvenile, and mature wood.

Pilot scale.
Drums of southern pine chips were obtained from a local mill for the pilot scale trial. Half of the drums were placed in a freezer to be used as nonaged, nontreated controls. The other half of the drums were opened and treated as explained below. Nonsterile chips were used for the pilot scale trial.

Inoculation and Fungal Growth Period

Lab scale.
Nonstaining *O.piliferum* was grown at IPST in shake flasks. Fungal suspensions were centrifuged after 36 hours. Pellets from centrifugation were homogenized and diluted before being pipetted into plastic bags containing about 1200 g (wet weight) of wood. Chips were inoculated with 1.61×10^7 fungal cells for every 100 g of

chips (wet weight) and incubated at 25°C for one-, three-, and five-week periods. Nontreated controls were also incubated and aged for the same time periods. Significant growth of *O.piliferum.* wild-types occurred on all aged controls.

Pilot scale.
Nonstaining *O.piliferum* frozen product was diluted and sprayed with a garden sprayer onto the wood chips as each 55-gallon drum was opened. Each drum of chips was treated with 5.61×10^{11} fungal cells of Cp. The fungus was allowed to grow for five weeks on the wood chips in a small room, where temperature during the incubation period ranged from 18-26°C. Aged controls were not included in this trial, due to previous analyses of aged controls which showed wild-type *O.piliferum* as the primary species present on the wood.

Refining

Lab scale.
A Sprout-Waldron atmospheric refiner equipped with 12-inch, D2B505-patterned, 440C stainless steel plates was used to refine the fungal-treated and nontreated chips. Motor load was measured with a Hall Effect power transducer and recorded with a reporting integrator. Chips were refined with peripheral water flowing into the refiner casing. Consecutive passes were carried out at 20% consistency. Refining was executed in 5 to 7 refining passes. Pulp was retained for latency removal, and handsheet production ranged in freeness from 250 to 30 mL CSF.

Pilot scale.
Primary refining was carried out in an Andritz Sprout-Bauer model 418 pressurized double-disc refiner at 2.76 bar for 2 minutes. Secondary refining took place in an Andritz Sprout-Bauer model 401 atmospheric double-disc refiner. Refiner plate 36104 was used for each refining pass which was at 1200 rpm.

Dichloromethane Extractions and Handsheet Production

Lab scale.
Wood meal samples from chips used for refining were extracted with dichloromethane (dcm) according to TAPPI Test Method T-204 after grinding to 10-mesh size in a Wiley mill. Freeness testing, handsheet production, and physical- and optical- property testing were carried out according to TAPPI Test Methods. Fines contents and fiber lengths were estimated from Bauer-McNett classification (4).

Pilot Scale.
Freeness testing, handsheet production, physical and optical property testing were carried out according to TAPPI Test Methods. Fines contents were estimated from Bauer-McNett classification (4), while fiber lengths were determined from Fiber Scan™ data.

Data Analysis
Statistical analyses of the data were performed. Multiple regression analysis with *O.piliferum* treatment, incubation time, and specific energy consumption designated as independent variables was performed, while freeness, fines content, tensile, density, tear, z-span, fiber length, and scattering coefficient were used as dependent variables.

For the statistical analysis of the pilot scale trial, only specific energy consumption and *O.piliferum* treatment were used as independent variables. Incubation time was not varied in this experiment and was not included as an independent variable for this reason.

RESULTS AND DISCUSSION

Extractive Results

Lab scale.
O. piliferum treatment reduced extractive content from 25-45% below nonaged, nontreated control chips and 7-16.5% more than wild-type fungi on nontreated, nonsterile wood chips aged for one-, three-, and five-week time periods (Fig.1).

Fig. 1. Extractive Content vs. *O.piliferum* Residence Time in Extracted Wood Meal

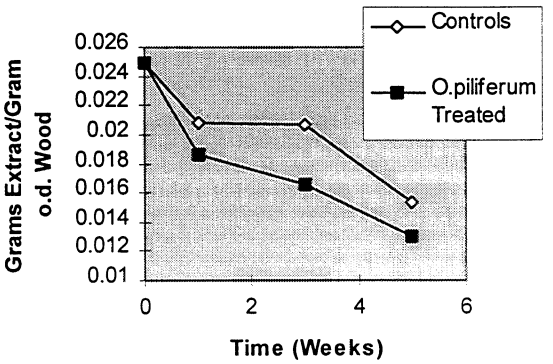

Fig. 1.

Strength Results
The multiple regression equations were all significant and yielded strong multiple coefficients of correlation (Table I

and Table II). Equivalent refining energy input to treated and nontreated chips and resulting pulps did not produce pulps with meaningfully different freeness levels.

Table I. Multiple Regression Equations and R^2 for Dependent Variables from Lab. Scale Refining Runs (95% Confidence Level)

Dependent Variable, y	Regression Equation, where:x_1=SEC, x_2=Incubation Time, x_3=Cartapip Presence	R^2
CSF	$y=-2.986x_1 + 0.24x_3 + 8.629$	0.962
Fines	$y=21.85x_1 - 1.212x_2 - 3.527x_3 + 16.827$	0.903
Tensile Index	$y=31.54x_1 + 0.83x_2 + 26.147$	0.969
Density	$y=161.15x_1 - 19.33x_3 + 56.29$	0.923
Tear Index	$y=1.327x_1 + 0.1182x_2 + 0.7973x_3 + 0.8403$	0.921
Z-Span Tensile Index	$y=26.87x_1 + 0.939x_2 + 3.895x_3 + 23.918$	0.918

Table II. Multiple Regression Equations and R^2 for Dependent Variables from Pilot Scale Refining Runs (95% Confidence Level)

Dependent Variable, y	Regression Equation, where:x_1=SEC, x_2=5 week Cartapip Treatment	R^2
CSF	$y=-128.05x_1 - 64.84x_2 + 1448.14$	0.9345
Fines	$y=3.93x_1 + 1.99x_2 - 4.045$	0.7784
Tensile Index	$y=3.701x_1 + 3.21x_2 - 11.47$	0.9341
Density	$y=30.49x_1 + 20.145x_3 + 11.86$	0.8696
Tear Index	$y=10.596x_1 + 0.95x_2 - 0.584x_1^2 - 41.022$	0.8021
Z-Span Tensile Index	$y=15.755x_1 + 0.297x_{12} - 0.876x_1^2 + 7.478$	0.7944

Fungal treatment did not reduce energy usage to produce these pulps in laboratory scale refining runs. The pilot scale trial, however, did reflect decreased energy requirements for pulp production. Strength, power, and length relationships given in Figures 2, 3, 6, 7, 8, and 9 represent upper and lower limits for the multiple regression equations.[1] (Lower limit - no Cp/incubation time equals zero; upper limit - Cp is present/incubation time equals five weeks.)

The same amount of energy input in the fungal-treated chips produced greater tensile strengths in both trials (Figs. 2 & 3).

Fig. 2. Change in Tensile Strength with S.E.C. (Lab Scale)

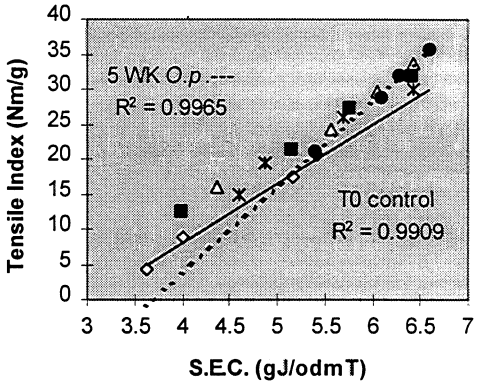

Fig. 2.

Fig. 3. Change in Tensile Strength with S.E.C. (Pilot Scale)

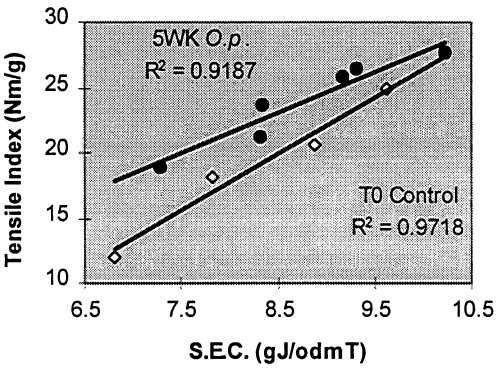

Fig. 3.

Generally, tensile, tear, and zero-span tensile strengths all increased with *O.piliferum* treatment. Tear strength in laboratory scale Cp treated pulps increased from 18 and 35% over strengths of three- and five- week control pulps, respectively (Fig. 4).

[1] Symbols in the figures are: ◊ Diamonds are nonsterile, time-zero controls;
Triangles are nonsterile controls aged three weeks;
* Stars are nonsterile controls aged five weeks;
■ Squares are three-week *O.p.* treatments;
● Circles are five-week *O.p.* treatments.

Fig. 4. Tensile-Tear Relationship (Lab Scale)

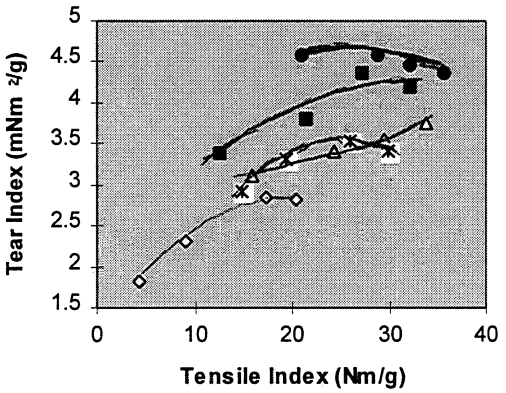

Fig. 4.

Tear strength increases for the pilot scale trial were not as dramatic as evidenced in the laboratory scale work (Fig. 5). At pilot scale tensile index values greater than 18Nm/g, the tear strength of the Cp treated sheet is greater than the control. At a tensile index value of 25Nm/g the tear reaches its maximum, which is 17% greater than the tear strength of the control.

Fig. 5. Tensile-Tear Relationship (Pilot Scale)

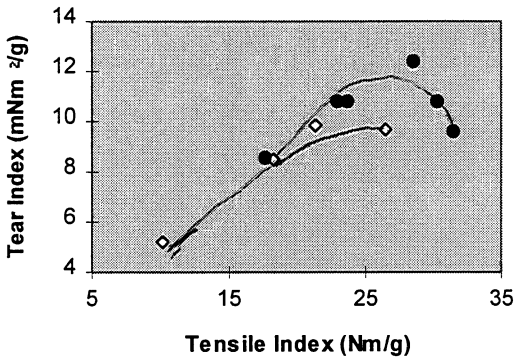

Fig. 5.

As shown in Figures 4 and 5, tear at a given tensile strength increased, indicating a probable increase in individual fiber strength, supported by zero-span data (Figs. 6 & 7). The range of zero-span indices for the laboratory scale pulps (Fig. 6) is much greater than the range for the pilot scale pulps (Fig. 7). Both figures, however, show that fungal treatment yields fibers with greater intrinsic fiber strength.

Fig. 6. Zero-Span Tensile - Specific Energy Consumption Relationship (Lab Scale)

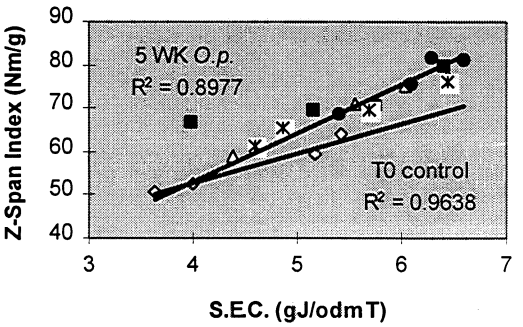

Fig. 6.

Fig. 7. Zero-Span Tensile - Specific Energy Consumption Relationship (Pilot Scale)

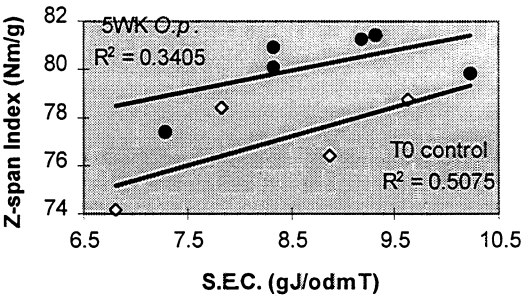

Fig. 7.

Fungal treatment also yielded laboratory pulps with fiber lengths longer than those in untreated pulps (Fig. 8). Fiber lengths in the pilot scale-produced pulps (Fig. 9) were not as distinctively different as in the laboratory case (Fig. 8). Pilot scale Cp pulps are at most 0.275 mm shorter than the control pulps, while laboratory scale Cp pulps are generally longer than the controls. Both sets of data appear to converge as energy input is maximized.

Fig. 8. Change in Fiber Length with Specific Energy Consumption (Lab Scale)

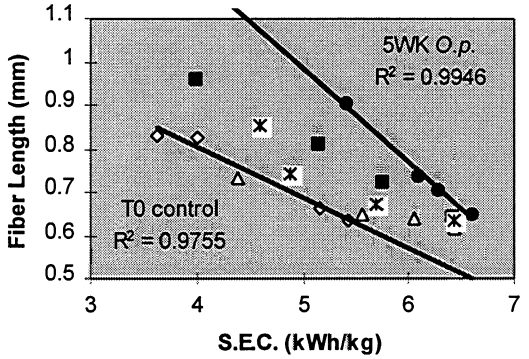

Fig. 8.

Increased fiber length contributes to increased tear strength as does intrinsic fiber strength. Laboratory scale fungal treatment of chips yielded pulps with significant decreases in fines content concurrent with increased fiber lengths. Pilot scale pulps did not exhibit this type of behaviour.

Fig. 9. Change in Fiber Length with Specific Energy Consumption (Pilot Scale)

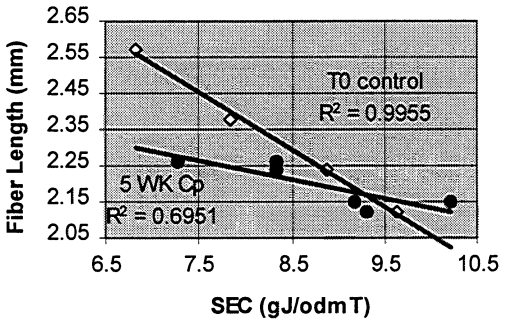

Fig. 9.

Another result which differed between the two trials was the extent of fungal growth. Chips in the laboratory scale trial exhibited 95% nonstaining *O.piliferum* growth, while about 59% of the chips in the pilot scale chips showed nonstaining *O.piliferum* growth. Wild-type *O.piliferum* growth was found on 85% of the chips used as aged, nontreated controls in the lab. scale study. Wild-type *O.piliferum* was also present on treated chips in both studies. The laboratory scale nonstaining *O.piliferum* treated chips had 9% wild-type growth, while the pilot scale chips had 14% wild-type growth.

Wild-type *O.piliferum* ultimately results in the same pulp and handsheet properties as induced fungal treatment but not to the same extent (Fig. 2, 4, 6, and 8). Examination of the laboratory scale results suggests that fiber strength and fiber length are significant contributors to the additions in strength. The pilot scale trial might lead one to believe that fiber length is not an essential component of the strength forming mechanism present with fungal treatment. However, the dense fungal coverage visible in the laboratory scale trial after three and five weeks was not that extensive in the pilot scale trial. This visual observation was supported by the fungal growth analysis described in the preceeding paragraph. As a result, it is the author's conclusion that fungal treatment may well yield pulps with increased fiber length. Another possible explanation for the difference in fiber lengths may have to do with the refiners used for the studies. Lab. scale refiners have been shown to yield pulps with lower overall tear strengths than pilot scale refiners (5).

SUMMARY AND CONCLUSIONS

Fungal treatment effects of *O.piliferum* on handsheet strength properties were studied by producing refiner mechanical pulps from chips treated with fungus for varying time periods. Nonstaining *O.piliferum* treatment decreased extractive levels and increased tear, tensile, and zero-span tensile strengths over and above growth with *O.piliferum* wild-types. *O.piliferum* treated chips refined with greater fiber lengths, which may partly account for increased tear strength in laboratory scale studies. Intrinsic fiber strength is probably also a major contributor to increased tensile and tear strengths. The *O.piliferum* treated pulps resemble chemimechanical pulps[6] , where strength properties increase while freeness changes minimally. Strength development in chemimechanical pulps is caused in part by larger numbers of acid groups of the fiber surface. Fiber and/or extractive chemical compositional changes may ultimately explain strength differences.

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